AN INTRODUCTION TO BAR CODES

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Abstract

In 1973, printers were concerned about the added complexity of printing the newly adopted Universal Product Code (UPC). Now most items sold in grocery stores are source marked with manufacturer and item identification encoded into a UPC symbol, then successfully scanned at the point of sale. In addition, bar codes have become a key tool for improved productivity in manufacturing and distribution as well as retailing. Printers who understand bar code systems requirements have opportunities for additional business, supplying a wide variety of printed labels, packaging items documents and other materials with correctly produced symbols. The printer may also improve his own operation by using timely, accurate, inexpensively collected information from bar coded documents including standardized manufacturer's labels on supply items. This paper outlines bar code system fundamentals, compares symbologies, and reviews printing methods, quality control requirements and applications of interest to the printer.

Introduction

There have been tremendous technological strides in data processing hardware over the last few years. Mountains of reports can easily be generated. The newer personal computers are able to execute millions of instructions each second. This performance increase is in contrast to the main form of data input, hand keying from various documents at a rate of a few characters each second and a few errors each minute. The result is data that is too old or inaccurate due to input delays and errors. "Computer errors" is the frequently used excuse for problems with billing statements which were probably the result of erroneous input. Most of us who have used computer generated production or inventory reports have spent hours correcting errors due to incorrect input. The rule of thumb is one error for each 50 to 100 keystrokes. In addition, most many of us have slow input rates and high error rates when keying data. If we hand write data, it frequently has poor legibility, so is difficult for input clerks to read. Instrumentation has been interfaced directly to computers for a number of years. A number of automatic identification technologies have been developed to reduce data input problems by eliminating manual keying of data.

Bar codes are the most familiar form of automatic identification and automated data entry today. Bar codes are also the most interesting to printers because they are both a saleable product and a useful management tool for increasing productivity, by tracking work and inventories and for generating the accurate, timely data needed to make intelligent business decisions.

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At the spring 1973 GATF meeting in Pittsburgh, many printers received their first introduction to bar codes in the form of the Universal Product Code (UPC). At that time, there was considerable concern about effect on appearance of the merchandise, acceptance by consumers, printing to specifications, obtaining film masters and color selection.

Today, the consumer generally expects to see the UPC symbol on packaging, accepts the lack of price labels, is familiar with laser scanners and even tolerates point of sale equipment that announces the price to anyone close enough to hear. The added graphics is taken for granted unless needed for proof of purchase to obtain a rebate.

Printers around the world successfully print millions of UPC symbols each day. Many benefits are being realized in the grocery industry, where over 13,000 stores, in the United States alone, have installed scanning systems.

Following the success in the grocery industry and taking advantage of the existing widespread source marking of retail packaging, mass merchandisers have started getting into the UPC business. In late 1986, the National Retail Merchants Association (NRMA) replaced its endorsement of Optical Character Recognition (OCR) with UPC as its suggested voluntary standard for general merchandise retailers.

The familiar, all numeric, UPC symbol tells the point of sale computer where to look in its memory for the identification of the product manufacturer, item description and the current price. Magazines, paper back books and greeting cards carry an extra segment of the symbol which can be translated into a date code or other specific information for returns and inventory processing.

Now that there is a large capital investment in scanning equipment and computers, many retail chains have started checking scanning performance and dunning suppliers who cut into expected system productivity with symbols that do not perform as expected.

Before UPC, the bar code business was estimated at $100,000/year. With UPC demonstrating the concept, and micro-electronics making it practical and affordable, interest grew in other bar code applications. In 1974, the alpha-numeric Code 39 was introduced, simplifying many applications for manufacturing and warehousing. Code 39 is now the primary code specified by the Department of Defense (LOGMARS), Auto industry (AIAG), Health Industry (HIBCC) and the Graphics Communications Association (GCA). Libraries and blood banks have used Codabar. MSI/Plessy is used for many behind the scenes retail operations such as inventory and automated reorder. Interleaved 2 of 5 is used for some industrial applications.

Alternate Automatic Identification Technologies

In addition to bar codes, a number of technologies are being used for automated data input. The working environment, data security needs and cost factors affect technology selection. The following are four of the systems which are most widely used today.

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Magnetic Stripe

Magnetic stripe technology, which is a digital version of tape recording, is most familiar as used on credit cards, identification cards, retail tags, hotel room keys and reusable tickets. The technology is easy to read and write and relatively secure. The source of materials is limited and relatively expensive. The data can be updated on the fly as is sometimes done on mass transit systems. The user purchases a ticket for an amount which is magnetically recorded on the ticket. As the customer goes through the system, entry and exit points are recorded and the ticket value is adjusted. When the ticket is of no value, it is reclaimed by the automated equipment and can be recycled.

MICR

Magnetic ink printing is most familiar on bank checks. The printing is done with special inks incorporating particles which can be magnetized.

OCR

Optical Character Recognition (OCR) is widely used in many areas where re-entry of text is required from standard forms. A large application is in the area of Remittance processing. Account numbers and related data are printed on computer generated billing forms and automatically re-entered when the document is processed.

Until late 1986, OCR was the standard for data entry using Electronic Point of Sale (EPOS) equipment recommended by the National Retail Merchants Association (NRMA). UPC was not readily printed by retailers and relatively expensive computer memory was required to provide the necessary information capacity for tracking the tens of thousands of Stock Keeping Units required in the general retail market. Maintenance of large look-up tables was not practical with the cost and technology limitations of the computers of the early 1970's. OCR provided a means of recording more detailed information on paper. Standards often called for four or more lines of data to be scanned. Large chains such as J. C. Penny and Sears invested millions of dollars in the technology which is still in use in some locations.

The expectation of efficient data collection has seldom been accomplished in practice. The operation of the hand held, pistol-like readers, in the retail environment, has not been satisfactory for a variety of reasons. The equipment functions to decode a multi-dimensional image are more complex than those required by other technologies. The reported character substitution rate is about 1 in 10,000. Operator training seems to be lacking. While the printing of the special characters seems quite straight forward, the critical parameters are very difficult to measure so that continuing compliance with specifications is maintained. In late 1986, the NRMA yielded to pressure from retailers to adopt UPC as a voluntary standard.

The reduced cost of computer technology which is making wider application of UPC possible is also creating new opportunities for OCR. A new generation of relatively inexpensive OCR page readers is being developed which is compatible with today's microcomputer systems. These page readers are used for input to word processors in offices and for typesetting.

Vision systems are also being developed which are able to read conventional characters for industrial applications.

Bar Codes

Bar codes are the prevalent common means for automatic data input in use today. They are low in cost, highly reliable and easy to produce and use . In simple terms, the bar code is a way to encode the ones and zeroes of computer data on paper and simplify its repeated reuse. The symbol is only analyzed in the dimension across the bars, the height of the symbol gives redundancy to the data, increasing the probability of a successful decode. They can be read by a contact device or, in contrast to the technologies discussed earlier, remotely, at high speed.

Bar Code Formats

There are about fifty (50) bar code formats in use today. A few symbologies are used for the majority of applications. One of the keys to selection of a symbology today is interaction requirements and the availability of equipment. The grocery industry created a market for UPC which is expanding into other retail environments because so many products are source marked. The complex symbology requirements, which will be discussed later, and limited data encodation capability would probably not be chosen for other applications.

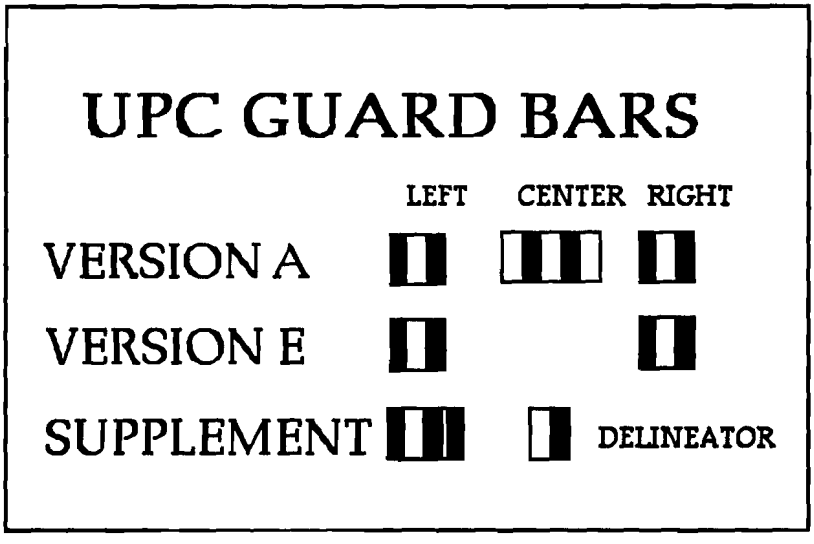
The automotive industry and the Department of Defense chose Code 39 as a standard. Not only does Code 39 have many favorable properties, the proliferation of users also leads to increased availability and lower cost for equipment and other support. Code 39 has also become the standard for the health and graphic arts industries and is being adopted for many corporate programs. Interleaved 2 of 5 is selected for some industrial uses where all numeric data is adequate or space is a consideration. It was also selected for the Universal Container Symbol for retail unit load containers. Codabar has been a standard for blood bag identification and in libraries. MSI is used for some retail inventory support functions and shelf labels.

Bar Code Structure

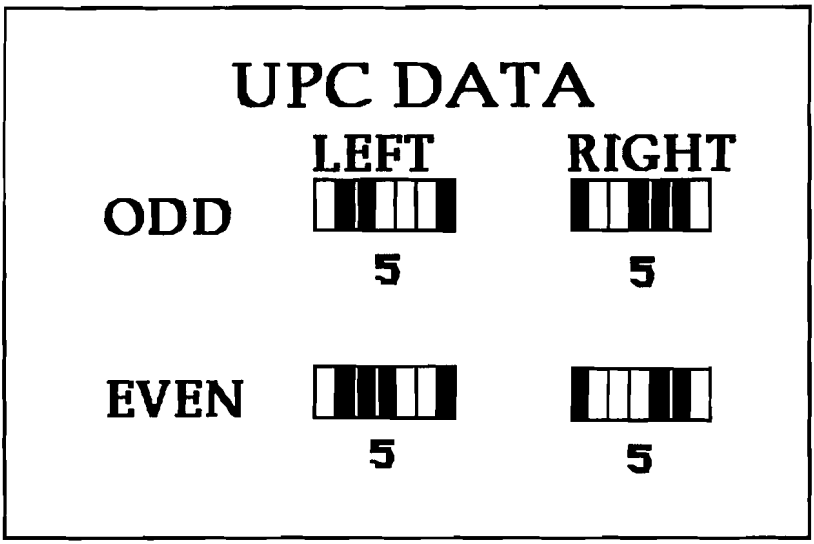
The basic elements of a bar code symbol are the same for all symbologies. There must be a quiet space on each side of the symbol so that the scanner can isolate the symbol from other graphics. Start and stop characters are used by the reader to limit the decoded area. Data characters are translated into specific information.

UPC Structure

The UPC coding structure is relatively complicated. It was designed for flexibility in application and reliability in mass printing.



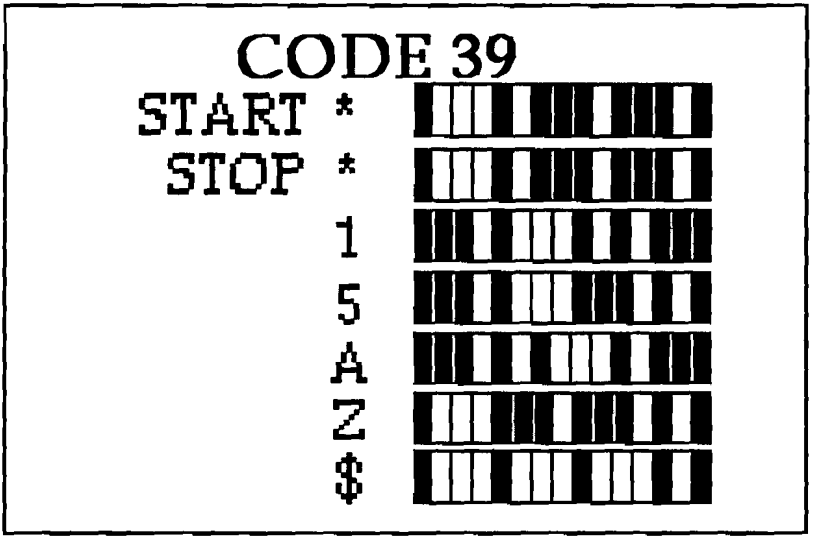
UPC characters are encoded continuously. Each character is made up of seven (7) modules which are divided into two bar and two space elements. Each element can be from one to four modules wide. Each character can be composed four ways depending on its position on the right or left side of a symbol or the character may be odd or even parity, if the application requires. Fortunately, computerized film master generators are used to produce symbols according to specifications.



The form of the symbol includes a number system character, a five digit manufacturer's identification number , a five digit item identification and a check digit. Under certain conditions, the data can be compressed to six digits (Version E), reducing the real estate required by the symbol. Outside of the United States, an additional digit is used to encode the country of origin.

Code 39 Structure

Code 39 was developed in 1974 in response to the need for an alpha-numeric code. It is relatively simple in structure with wide elements representing a binary one (1) and narrow elements representing a binary zero (0). Each character is discrete. The name comes from the three (3) binary ones of nine (9) elements for each character. Because there is a flexible inter-character space and only two element widths, simple printers can produce acceptable symbols. Numbers, the alphabet and seven special characters can be encoded directly. The rest of the 128 ASCII characters and control code set can be produced from combinations of special characters and alphabetic characters.

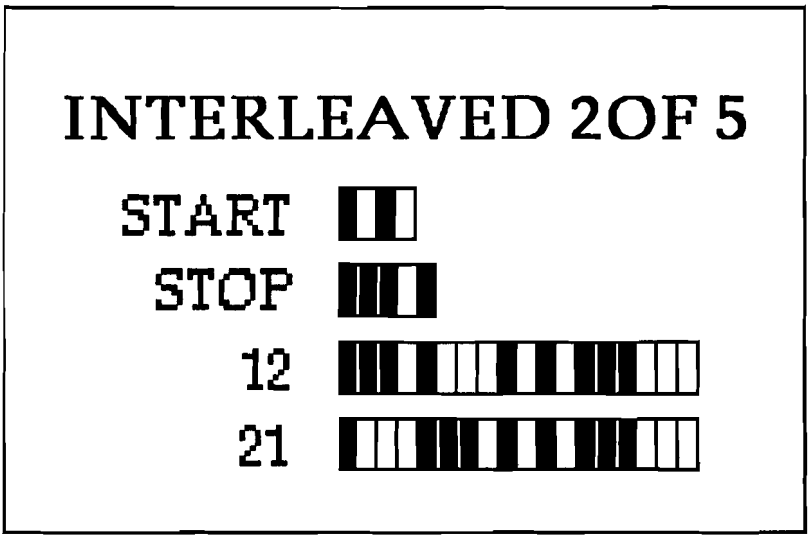


Tests of actual samples of Code 39 bar codes have resulted in substitution error rates of less than one error for each million or more characters scanned. Fair quality printing, resulting in one substitution error for each one million characters scanned, is expected to produce a first read rate greater than 90%.

Code 39 has become the most widely used bar code for industrial applications.

Interleaved 2 of 5 Structure

Interleaved two of five was developed as a high density code for a given minimum element width. The high density results from encoding alternate characters in the bars and spaces. The symbol must always encode an even number of digits.



Each character consists of five elements, the two wide elements representing binary ones and the narrow elements representing binary zeroes. Only numeric data can be encoded.

Caution should be exercised with high density symbols, the dimensional tolerances are very small.

Interleaved 2 of 5 was adopted in 1981 as the standard symbology for corrugated shipping containers used in the grocery industry (UCS).

Bar Code Reading Devices

A variety of types of readers are used to translate black and white bar codes into electrical impulses which can be recognized by a computer or data processing system. They all consist of a source of energy and a detector for the reflected energy, much like a densitometer. The signal from the detector is processed with a decoding algorithm which determines what width bar or space has been seen by the detector and translates the string of digital impulses to usable data.

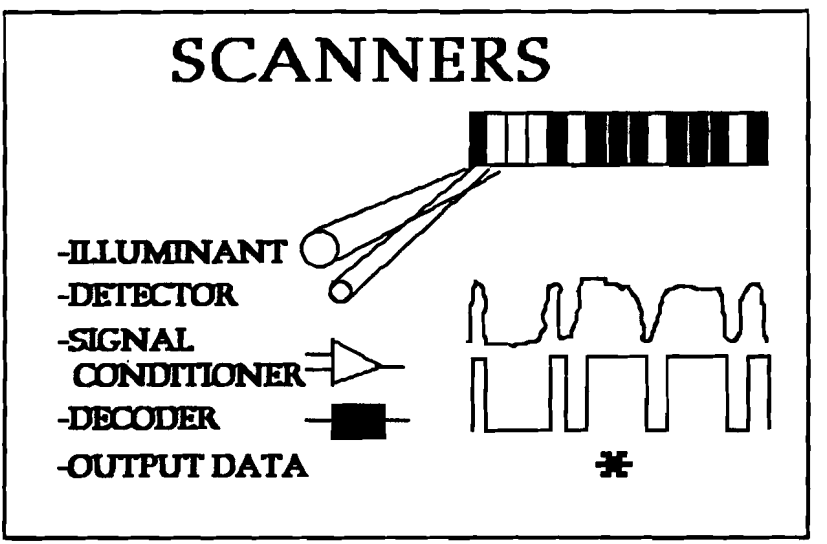
Reader light sources usually emit in the red spectrum, at 633 nanometers or in the infra-red spectrum, from 780 to 900 nanometers. Using the infra-red sources restricts the choice of inks for printing the symbols. Dye based inks are transparent , so they are not seen by the IR scanners. This characteristic is useful if visual security is needed. It can be achieved by

printing a bar code with a carbon based ink, then covering it with a dye-based ink. Also, dirt and grease are often transparent in the infra-red spectrum, and do not interfere with reading these symbols. At least one supplier prints invisible symbols which fluoresce when illuminated by the reader.

Scanners

Scanners are usually non-contact devices, using lasers or laser diodes for energy sources.

Most scanners have moving beams. The most complex beam movement is typified by the familiar Point-of-Sale scanners which scan at hundreds of times per second, in a variety of directions, simplifying the alignment of the symbol and the beam for high operator productivity.



Fixed industrial scanners generally move the beam in one direction and wait for the label to move past the scanner. Some of these scanners do not move the beam at all, but depend upon movement of the label for scanning.

Hand held laser guns are available to work in either mode, automatically moving the beam or expecting the operator to provide the scanning

Wands

Wands use the same operating principles as scanners, but work in contact with the symbols. Their depth of field is usually limited to a few hundredths of an inch. Light emitting diodes are the most common energy source. The operator scans the code by moving the wand across the symbol.

Bar Code Printing

Various methods are used to satisfy print bar code printing needs depending on the number of copies needed, the urgency of the need, permanence and quality requirements.

Batch printing of large numbers of copies of the same symbol is typified by UPC and UCS. A film master is used to make printing plates for conventional processes.

Alternatively, a large number of symbols is needed, but each is predictably different, as for serial number labels, a computer driven or intelligent stand alone printer may be used. The technology includes laser driven electrostatic, ion deposition, magnetic and photo typesetters. Some of these printers are being interfaced to label presses so that symbols which encode changing data can be added to conventionally printed graphics.

Demand printers are used when needs are unpredictable but there is urgency for the output. These devices may be computer driven or self-contained. The technologies include the conventional dot matrix impact, laser and even ink jet. New technologies include thermal dot matrix using a heat sensitive media and thermal transfer using a heat sensitive ribbon which is transferred to the media. The newer dot matrix technologies use improved dot shapes to improve bar edge quality.

Quality Control

I heard the statement recently, "If they can't read my bar codes, how will they know who to pay?" The following examples show how realistic the statement is.

The Automotive industry is leading the way with paperless warehouses where receiving, put away, picking and shipping are done without generating a paper document.

A leading supplier to hospitals provides portable terminals with bar code readers which can be used to inventory supplies and generate electronic purchase orders. The ease of use and reduced paperwork have helped the supplier to secure a major market share.

To make these systems work, bar code performance is critical. A shipment may now be rejected for poor bar code performance as easily as failure of the labelled components to meet specifications.

The grocery industry and mass merchandise retailers are insuring their investment in scanning equipment by working with vendors whose symbols do not perform as expected. Products with poor symbols interfere with user productivity improvement programs in retailing and industrial environments and

may be returned to suppliers for correction, like any products with intrinsic defects. At least one state agency will shut down a retail store liquor department if it does not pass an audit of prices charged after product scanning.

Documentation is available from using companies, user groups, industry associations and ANSI. The standards describe symbology, industry encoding requirements, location guidelines and printing specifications. Sources are listed in the bibliography at the end of this paper.

Application

The first step is visually checking application of the correct symbol and confirming that the physical requirements of the symbol size, white space location and orientation are met. In the 1986 study of UPC problems, by the Uniform Code Council (UCC), two percent of the problem symbols were reverse printed . Thirty-one per cent had incorrectly selected or applied symbols. (See reference 1)

The UPC is usually printed in the midst of other graphics which makes the job of the scanner much like looking for a needle in a haystack. The Uniform Code Council publishes specifications for preferred symbol locations and clear area so that the scanner can separate the symbol from other graphics.

Application of industrial bar codes and the UCS which are frequently read by fixed scanners as containers move on conveyors are subject to user group specifications for symbol size and location.

Symbols which are to be read manually, with a wand, need at least 1/4 inch of free space at each end, a minimum height of 1/3 inch or 1/6 of the symbol length to be reliably scanned.

Encodation

This step is a machine check of encodation of the correct data. Generally, a visual check will insure that the data is correct. Most symbols are encoded by a computer operated printer or film master generator, so that the data in the bars matches the human readable characters. In the 1986 UCC study , 15 per cent of the problems symbols scanned differently than the human readable characters. Because many of today's scanning retailers give the product to the customer at no cost if the incorrect price is charged, the retailers are checking symbols and working closely with suppliers to eliminate problem sources.

Symbol formatting problems also can be determined at this check. Recently, a pre-production set of labels was received with correct human readable characters, but the programmer neglected to include the start and stop characters. The labels were unscannable.

Contrast

In order to find and decode the symbol, the scanner must be able to differentiate between the dark bars and the light background. The spectral characteristics and minimum contrast are specified for each symbology and application. In the 1986 UCC study, eleven per cent of the problem symbols had inadequate print contrast.

The UPC is designed to be read by a Helium-neon laser which emits at 632.8 nanometers. The UPC specification calls for measurement by a system which approximates the laser response. We have found that not all instruments, even from the same manufacturer, agree on reflectance measurements of colored samples. This is especially true of red and magenta samples which have steep reflectance curves in the critical region. (This problem should not be new to densitometer users).

Industrial bar codes may be read by red light scanners or infra-red scanners. The critical wave lengths are specified for each application. The critical aspect of symbols to be read in the infra-red is that dye based inks are transparent. Carbon based blacks or suitable pigments are required.

The Print Contrast Signal (PCS) is calculated from the light and dark reflectance.

PCS = (Light reflectance - Dark reflectance)/ Light reflectance (1)

Dimensional Accuracy

The scanner decodes a bar code by determining the relative width of the bars and spaces. To prevent ambiguity between the widths of the elements, dimensional accuracy is required. Each printing process has measurable variability. By selecting an appropriate size for the symbol and compensating for print gain, nearly any process can produce usable symbols. In the 1986 UCC study, forteen per cent of the problem symbols did not comply with dimensional specifications.

The only way to insure the desirable correct decode and first read rate is to print within the published dimensional specifications. This can only be determined by physical measurement. Obviously, manual measurement of all the critical dimensions of a symbol is impractical so several companies have developed automated equipment which scans, decodes, and compares the achieved dimensions to specifications. A message is generated for the operator indicating in or out of specifications and, in some cases, providing dimensional analysis of the symbol. The dimensional analysis is needed for press adjustment or optimizing film master bar width reduction.

The developers of the UPC provided a printability gauge which could be used to determine system gain and variability. Associated charts were provided so that the printer could determine the correct size symbol and bar width reduction to use in film master preparation to insure correctly printed symbols.

Industrial code specifications do not document these steps. The UPC techniques are adaptable. The same principles can be used to adjust electronic demand printing systems to produce acceptable results. This entails electronic bit-fiddling to compensate for printer non-linearities.

Many symbol printers use a bar code reader to evaluate symbol quality. This may be a successful practice if the symbols are always read by the same type of reader, in the same condition. Not all readers use the same decode algorithm, aperture or light source. Therefore, they use different amounts of the tolerance budget, leaving different acceptable error margins for the printer. Measurement of the symbol with a verification device to insure compliance with specifications is the only reliable way to predict successful readability.

Markets and Opportunities

All current predictions for growth of bar code applications and markets are very optimistic. Expanding use for non-grocery retailing will greatly increase demands for source marked packaging. Manufacturers are benefiting from better ability to service their customers through improved inventory control, electronic re-ordering and merchandise tracking. Unit loads are being marked with the UCS for tracking through the distribution system and the users warehouse. All of these benefits and the increasing industrial applications of bar code systems are increasing demand where some experts believe that only five % of the market has been reached.

One VCR manufacturer is equipping recorders with bar code readers and promoting bar code printing of timing and channel information in program guides so that the user can set up future recording by scanning the printed symbol.

Applications

Bar codes are becoming much more than a source of printing business for the printer. Like other businesses, there are opportunities in the printing world for improved tracking of work in progress, material control and operating costs.

Tracking of materials can now start at the receiving dock. The Graphic Communications Association (GCA) has published the Graphics Industry Bar Code (GIBC) format for bar codes on graphic arts materials such as photographic film, printing plates, offset blankets and printing inks. The standard uses Code 39 in a format patterned after the Health Industry Bar Code recommendations. The primary information includes a Labeler Identification Code (LIC) issued by the GCA, a product or catalog number (PCN) and a unit of measure identifier (U/M).

The Graphics Communication Association has developed the EMBARC specification for bar coding paper stock shipments and electronically transmitting manifest information to the customer's computer. The system allows the customer computer to carry the essential data describing materials, such as grade, basis weight and quantity, before they are received, and to have the

records activated by scanning the materials at receiving. Roll specific data can be maintained throughout the printing operation, without writing or keying any information.

Systems now available can track workers time and attendance, time by job, movement of materials, etc. The data is collected by the worker, at or near his work station. The data can be analyzed using available programs which run in popular small computers or large host systems. Management imagination is the only limit on possible applications. Data input becomes as accurate as is possible and can be available in real time.

Summary

Bar codes are an extension of the data processing system memory which can be inexpensively printed, then efficiently and accurately recalled on a timely basis for work and materials tracking, facilitating improved productivity and better quality data for the management decision making process. There are increasing opportunities to produce bar coded material for sale to other users and to use the technology in house for his own benefit.

References

1. Private Correspondence, H. Juckett, Uniform Code Council, Dayton, Ohio, February 1987.

2. UPC Symbol Specification Manual, Uniform Code Council, Dayton, Ohio, January 1986.

3. Allais, David, Bar Code Symbology: Some Observations on Theory and Practice, Intermec Corporation, 1984.

4. Scanning, Coding and Automation Newsletter, Great Neck, NY (Monthly)